result from a range of causes including foliage growing into the signal path and gradually obstructing the signal, signal fades due to weather conditions or various forms of vehicular reflections, inability to get first Fresnel zone clearances on most paths involving low antenna heights at subscriber premises, and the damping or latency necessary to avoid oscillation in a closed-loop power control system. It is for these reasons that the minimum received signal level that the receiver can utilize must be protected rather than the signal level that is the design goal for the system.

When calculating the interference potential of the response stations, recognition must be given to the fact that the specific characteristics of individual installations will vary widely. Many of the characteristics will be determined by the physical situations found where the installations must be made. Antenna heights will be decided largely by the heights of the buildings or other supporting structures or objects on which the antennas will be mounted. Thus installations on single family homes will be limited to the height of the roof plus the length of any mast that the aesthetic sensibilities of the homeowner find acceptable; installations on high rise buildings naturally will be forced to use much higher antenna elevations. The power that will be required to be transmitted to meet the received signal level design goal will then be dependent on the height of the transmitting antenna – lower installations likely requiring higher transmitted power than taller installations. Similarly, different antenna designs, with correspondingly different radiation patterns, are likely to be needed in the various situations. Of course, the different combinations of transmitter power outputs and antenna gains lead to yet other values for the effective isotropic radiated power of the installations.

Still other differences that will exist between diverse installations will be the percentages of time, the times of day, and the days of the week that response stations will be in use, actively communicating with the response station hub. This has significance when determining how much weight to give the contribution to interference from each type of response station installation. For instance, an installation in a home or individual garden apartment will produce an expectation of a comparatively low utilization percentage, while an installation in a high rise apartment building with a shared response transmitter will produce a much higher expectation in the evening when people are at home or on weekends, and an installation in an information-based business might produce a higher expectation still but only during business hours during the week.

In order to recognize in the calculation of interference the many varieties of installations, provision is made for dividing the response stations into groups based both on geography and technical attributes. Geographic grouping is accomplished by establishing regions within the overall response service areas of response station hubs. The regions can be defined arbitrarily by system designers but must be accurately described in the interference studies included with response station hub authorization applications. In order to ensure that the regions reflect concentrations of stations that are likely to follow concentrations in population, the methodology proposed for inclusion in the Rules and described below applies limitations to the freedom of design of the regions based on population densities.

Within the regions, further subdivision of the response stations into various types, called "regional classes" or simply "classes," is done by designating and enumerating sets of characteristics to be taken together in carrying out the interference analyses. The classes serve to put limitations on the numbers and characteristics of response stations that may be installed in each region under a response station authorization. Whenever it is necessary to exceed the authorized limits, an application for modification of the authorization must be filed.

The characteristics included in defining the regional classes are the maximum number of response stations in each class that may transmit simultaneously, the maximum antenna height of the class, the maximum effective isotropic radiated power (EIRP) in the forward direction, and the combined worst-case outer envelope of the radiation patterns of all antennas to be used in installations of that class (in all plane- and cross-polarization combinations, when both polarizations are used), all of which can be determined arbitrarily. The specification of the maximum number of simultaneous transmitters avoids the need to make complex calculations regarding utilization statistics that, of necessity, must be based on a series of estimates or assumptions that cannot be accurately predicted.

Interference Prediction Methodology for Response Stations

In order to tie together the many diverse facets of response system design that have an impact upon the potential for interference to neighboring systems and to allow prediction of the interference to be expected, a procedure for analysis has been developed and is proposed along with the other proposed changes to the Rules that are attached to the accompanying Petition for Rulemaking. The procedure is intended to assure the FCC that adequate studies have been performed of the complex interference relationships involving response station transmitters and to allow the licensees and operators of neighboring systems to determine for themselves that adequate interference protection is provided to their operations.

Three major steps

Three major steps are involved in the described procedure. First, a grid of points is laid out geographically to statistically represent the distribution of response stations within the response service area. Second, any regions and classes of response stations to be used in interference studies and to be installed in practice are defined. Third, the power to be used at each of the grid points to represent the transmitters in the vicinity of the grid point is calculated and used in the various studies.

Defining grid of points for analysis

The process starts by defining the location of the response service area (RSA) geographically and then defining all of the geographically-related characteristics of the RSA. The RSA can have any arbitrary shape desired and serves fundamentally to limit the area in which response transmitters that transmit to the particular response station hub will be located. It does not define the area from which it would be possible for the response station hub to receive signals. It is permissible for the RSAs of different hubs to overlap. It is also permissible for the RSA to have areas of arbitrary shape that are omitted in order to protect from interference incumbent ITFS receivers on adjacent channels. Special studies are required to demonstrate that adequate protection will be provided to those receivers by avoiding the installation of response station transmitters in the omitted areas.

Receiving antennas at the response station hub (RSH) may be sectorized, as described previously. When sectorized antennas are used, a method must be provided to discriminate between signals in the overlapping portions of the sector coverage patterns. One way to accomplish the required discrimination is with alternating signal polarizations from sector-to-sector. When this technique is used, it is necessary to include in the interference analysis methodology information about the layouts of the sectors so that the impacts of the differences in signal polarization between sectors can be taken into account. The sector layout is described in the same geographic terms as are used to describe the RSA itself, and the polarization of each sector is identified. Because the sectors will have portions of their respective coverage areas that overlap ("soft" boundaries), to make interference analysis somewhat easier, they are treated as having definitive boundaries determined by simply bisecting any overlap areas. Since the distribution of response stations should be roughly uniform within the relatively small area of overlap, treating the sector boundaries as sharp rather than soft should introduce little error into subsequent interference calculations.

To provide flexibility in managing interference from areas with differing populations of response stations, the RSA may be subdivided into regions that can also have arbitrary shapes. The regions serve to limit the areas in which response stations having different characteristics may be located and to limit the number of response stations in different portions of the RSA that may transmit simultaneously. This allows the RSA to have non-uniform distribution of response stations without requiring a detailed description of and rationale for the distribution.

Within each region, there is also provision for grouping response stations having different combinations of characteristics. Response stations having the same basic combinations are divided into classes that put limits on the several important features of a response station installation. These features include the height above ground level of the transmitting antenna, the effective isotropic radiated power (EIRP), and the worst-case combined radiation pattern(s) of any antenna models that are to be used in installation of the class of response stations. Also associated with each class is a limit on the number of response stations that may transmit simultaneously on any given channel or subchannel. The limiting or maximum values designated for each class are used in the subsequent interference analyses, thereby assuring that actual installations will not exceed the interference predicted to emanate from stations in the class.

Once all the geography and related aspects of the RSA are defined, a "measurement line" is defined ½-mile outside the RSA boundary. The measurement line is a smooth line that follows the shape of the RSA boundary and runs parallel to it. If there are any sharp points in the RSA boundary, a curved section having the point on the RSA boundary as its center and having a radius of ½ mile should be fitted between the straight or curved line sections parallel to the line sections of the RSA boundary on either side of the point. The measurement line identifies a locus of points uniformly spaced away from the boundary of the RSA on which specific measurement points can be defined.

So that it will be relatively easy to determine the locations of all the necessary measurement points on the measurement line, a starting point is established due north of the response station hub on the measurement line. The starting point is simply the point on the measurement line north of the response station hub that has precisely the same longitude as the hub.

Once the measurement line and starting point are established, additional measurement points are defined on the measurement line. Points are defined spaced every five degrees, as seen from the response station hub, or every ½ mile along the measurement line, whichever yields the largest number of measurement points. The net result of this is that, for those portions of the measurement line that fall within 5.73 miles of the hub, 5 degree spacing is used. For those portions that are over 5.73 miles from the hub, ½-mile spacing is used. (The 5.73 mile distance comes from determining the radius at which ½ mile along the circumference of a circle equals 1/72nd of the circumference, or five degrees.)

The dimensions selected for the separation of the measurement points come from a recognition that the beam width of any practical antennas will not be less than 5 degrees and thus at least one measurement point will occur in the main lobe of any antenna pattern to be used in the system. Also, near the edges of the RSA, the signal power received is predominantly the power from the back and/or sides of any nearby response station transmitting antennas. Thus the maximum separation of ½ mile is appropriate when measuring the accumulated signal power at a distance of ½ mile from the outside boundary of the RSA.

After the measurement line is laid out, a grid of points is established inside the RSA. The grid is intended to define a finite number of points that will represent the potentially large number of response stations that will be located in the RSA. This will facilitate the necessary interference studies by limiting the sources of interference to specific locations, in numbers that can be handled by available propagation analysis tools, rather than trying to study the interference from a more uniformly distributed field of interferors. While it is important to limit the studies to a number of representative points, it is also important to make sure that a large enough number of points is studied. That is the real purpose of the remainder of this portion of the procedure.

The grid is square and is set up running true north-south and east-west. The size of a block in the grid can be set arbitrarily to start; the following steps will determine whether a sufficient number of points have been included in the grid, i.e., whether the grid point spacing is small enough. With any particular spacing, the grid must be positioned so that one block in the grid surrounds the response station hub (RSH), with the four corner points of the block equidistant from the RSH. Any points that fall on the RSA boundary are to be included in the grid. Any points that fall on locations where it would be impossible to install a response station, such as within a body of water, are to be eliminated from the grid. Points that fall in places where there are currently no potential sites for response stations but which could with future development have such potential, such as in the middle of a forest, should be included in the grid.

The defined grid is divided into two groups using a checkerboard pattern or quincunx arrangement. The result of this division is that every other point on a north/south or an east/west line will belong to the same group, and adjacent points along those lines will belong to opposite groups. As a corollary to this arrangement, all the points along any diagonal will belong to the same group.

For the next step, each grid point is assumed to have a single response station at its position. The response station is assumed to have an antenna pattern with the combined worst case pattern of all antennas to be used in any classes in the region covering the grid point. (The method for ascertaining the worst case antenna pattern is described in the section below on Defining Regions and Classes for Analysis.) In systems that use antenna sectorization and alternating polarization between sectors, the combined worst-case antenna pattern is derived by treating each polarization, from any antennas to be used in both polarizations, as if it was derived from a separate antenna type, i.e. the patterns for both polarizations are entered separately into the process for deriving the combined pattern. The antenna is assumed to be oriented toward the response station hub. The response station is assumed to use the maximum EIRP defined for any class in the region covering the grid point.

Using these assumed characteristics for the response station at each grid point, a path loss study is performed from each grid point to each measurement point previously defined on the measurement line. The study is done using only the free space path loss from each grid point to each measurement point to determine the power flux density at the measurement point, without the effects of terrain and assuming a flat earth. The signal power reaching each measurement point from all of the grid points in each group is aggregated by converting from signal level in dBW/m^2 to power in $Watts/m^2$, adding up the power values, and then converting back to dBW/m^2.

Each measurement point now will have two values associated with it – one for each of the two groups of grid points. These two values are compared at every measurement point. If at all measurement points the two values are within 3 dB of one another, a large enough number of grid points was used. If the two values are not within 3 dB of one another at all measurement points, a larger number of grid points must be used, i.e., they must be moved closer together.

The objective of this test is to determine that enough points will be used in the interference analyses to follow that a relatively smooth field of signal levels results, as would occur with a large number of uniformly dispersed transmitters. If each half of the grid produces approximately the same signal level (i.e., within 3 dB) everywhere outside the RSA, the field is sufficiently smooth. When both halves of the grid are then used together in later studies, adequate smoothness and appropriate statistical representation of the response stations will be assured.

Defining Regions and Classes for Analysis

Regions and classes are used both to provide flexibility in the design of systems and to limit the interference that will emanate from the response service area (RSA) to that predicted in interference studies. Regions may be required by calculations of population density variations within an RSA but may be used even when not required. Regions may be defined arbitrarily as to their shapes, sizes, and locations, although the territory within a region must be contiguous. Regions within a single RSA must not overlap one another; RSAs themselves may overlap, however, so regions from different RSAs may also overlap. Regions are described geographically in the same fashion as used to circumscribe the RSA.

Within regions, at least one class of response stations must be defined; more are permitted to allow the tailoring of the interference characteristics used in analysis of a region to more closely match what will occur in practice. Within a region, response stations are assumed to be randomly distributed; for analysis purposes, they are assumed to be uniformly distributed. When classes are defined, the maximum number of transmitters that may be radiating simultaneously is included in the definition so as to put an upper bound on the interference that will be created.

The balance of stations in different classes that will actually be installed will be determined in the marketplace, so a means must be provided for changing the number of stations included in each class or changing the definitions of the classes themselves to reflect market conditions. Provision is made in the proposed changes to the Rules to enable the recalculation of the interference using different combinations of the maximum numbers of simultaneous transmitters. The same grid points, measurement points, and interference prediction methods are used in the recalculation. If the interference limits met in earlier calculations are maintained, the changes are treated as falling within the parameters of the original authorization for the response station hub, and only notification is required.

In order to assure that the interference predicted to originate from a region will reasonably closely match what will occur in practice, the methodology includes a process to reflect in interference studies the non-uniformity of the distribution of response stations that is likely to emerge. An assumption is made that the geographic density of simultaneous response station transmissions will approximately mirror the density of the population. Thus, however regions are defined, they are tested for the uniformity of their population densities using postal zip code territories as the basis for the test. The population contained within each zip code and the geographic area (in square miles or square kilometers) of the zip code are used in a computation that determines the uniformity of population within a proposed region. If the population density of each zip code within a proposed region is no greater than three (3) times the average population density of the region, the population density of the region is considered sufficiently uniform. Once a region passes this test, the response stations ascribed to the region actually may be placed anywhere within the region.

In some cases, it may be desirable to define regions containing only portions of zip codes. In these instances, the population of the zip code is assumed to be uniformly distributed over the zip code territory. The proportion of the area of the zip code that will be included in a region is determined, and the like proportion of the population of the zip code is assumed to be in the area included in the region. In other words, the population density of the zip code as a whole is ascribed to the portion to be included in the region.

The test for population density uniformity is a simple inequality in which the population density of each zip code is divided by the average population density of the entire proposed region. The resulting value must be three (3) or less. This limits the variability of the population density within a region, thereby making it legitimate to allow distribution anywhere within the region of the response stations attributed to the region. It also forces the formation of additional regions where the condition is not met. The inequality that expresses the required relationship is:

$$\frac{\left(P_{\text{zip}} / A_{\text{zip}}\right)}{\left(P_{\text{region}} / A_{\text{region}}\right)} \leq 3 \qquad \text{Where} \qquad \begin{aligned} P_{\text{zip}} &= \textit{Population in Zip Code} \\ A_{\text{zip}} &= \textit{Area of Zip Code}\left(mi^2 \textit{ or } km^2\right) \\ P_{\text{region}} &= \textit{Population in total Region} \\ A_{\text{region}} &= \textit{Area of total Region}\left(mi^2 \textit{ or } km^2\right) \end{aligned}$$

Classes of response stations are provided as a method for balancing the interference that will be caused and the types of installations. Since the prediction of interference must assume the worst case characteristics in case a large proportion of installations adopts those characteristics, classes allow the specification of a number of bounded sets of conditions. Only those installations that truly require the worst case characteristics, in terms of their interference generation, must then be counted in those classes. Other installations can be counted in classes that generate less interference, classes in which there can therefore be more response stations in operation at once.

The response station characteristics that must be specified for each class are the maximum antenna height above ground level (AGL), the maximum effective isotropic radiated power (EIRP), and the combined worst-case antenna performance of any antennas to be installed for the class. When both polarizations are used in a system, the combined worst-case antenna performance is determined for each polarization (including both plane- and cross-polarized patterns). Each of these characteristics is used to represent the entire class when conducting interference analyses. There is also a maximum number of response station transmitters that will be permitted to operate simultaneously that is associated with each class within each region. This maximum number of simultaneous transmitters applies to each channel or subchannel. There is no limitation on the number of response stations that can be installed in each class. It is incumbent on the operator to design the system so that the number of simultaneous transmitters of each class within any defined region is not exceeded.

In two places within the interference analysis methodology, there are procedures requiring the determination of combined worst-case antenna radiation patterns. In the first instance, the pattern for all antennas to be used in all classes of response stations occurring at each grid point must be ascertained. This is necessary in the procedure in which the number of grid points to be used in the interference analyses is confirmed. When both polarizations are to be used in a system, the combined pattern is developed by treating the patterns in the two planes, from any antennas to be used in both, as if they were co-planar and derived from separate antenna types.

The second instance is in the establishment of the classes of response stations as just described. In this case, only those antennas that are to be used for a class are included in the calculation for that class. When both polarizations are to be used in a system, combined worst-case antenna patterns must be determined for each polarization so that the appropriate pattern can be used at each grid point location in the subsequent interference analyses. Patterns for classes are required in both the plane-polarized and cross-polarized cases of the polarizations to be used in the system. It should be noted that there is nothing to prevent the use, in a particular class, at a later time, of an antenna that falls totally inside the pattern(s) used for interference studies.

The method for determining the combined worst-case antenna radiation pattern, no matter which antennas are included in the calculation, consists of setting the peaks of the main lobes of all the antennas to be combined to a common value (normally 0 dB), then taking the maximum radiation value in any given direction from any of the antennas involved as the value in that direction. This yields the outer envelope of all the antennas taken together as the combined worst-case antenna pattern. The same technique is used to calculate both the plane-polarized and cross-polarized patterns, both of which are used in the interference analyses. When a mix of antennas is used, it is quite possible that a single (probably low-gain) antenna will predominate in these calculations and that its patterns will be the worst-case for the group of antennas whose patterns are combined. Similarly, there is nothing to preclude the definition of a class using only a single antenna design, in which case its patterns will be the patterns for the class.

Calculating aggregated power from transmitters

The actual interference studies will depend upon assigning a power level representative of a proportion of the total power of the maximum number of simultaneously transmitting stations in a class to each of the grid points. This power is derived by dividing the total number of simultaneous transmitters of each class in each region by the number of grid points that fall within the region. The resulting number is the number of transmitters of each class allocated to each grid point. Distribution of transmitters within a region is assumed to be uniform over the grid points falling within that region. If some other distribution of transmitters is required, a different arrangement of the regions should be established.

The number of transmitters of each class assigned to each grid point is multiplied by the maximum EIRP specified for that class. This yields the aggregate power for each class, which is assumed to be transmitted from the highest elevation specified for the class. Each grid point can now be thought of as having at its location as many transmitters as there are classes in its region, with each such transmitter having a power equal to the total of the power from the number of transmitters of its class represented by its grid point.

In systems using both polarizations, e.g., where sectorized RSH antennas have alternating polarizations to discriminate between stations in the sector overlap areas, each grid point is assumed to represent response stations using the same polarization as the RSH antenna sector in the coverage area of which they are located. Depending upon the polarization of the station receiving interference in a particular interference analysis case, the appropriate plane-polarized or cross-polarized combined worst-case antenna pattern for the polarization of each grid point is used in the calculations of the undesired signal levels. When only a single polarization is used for response stations in a system, antenna sectorization does not matter, and either the plane- or cross-polarized pattern used in calculations for all grid points with respect to each neighboring system.

Using the power values for each class at each grid point, the required interference studies can finally be conducted. Each grid point is treated as having as many transmitters as there are classes of response station appearing there. Each transmitter is assumed to be at a height above ground level equal to the maximum for its class and to be using an antenna with a radiation pattern equal to the combined worst-case pattern defined earlier for its polarization. The power of each transmitter is that calculated as representative of the simultaneously operating response stations assigned to the grid point.

The studies to be conducted using these transmitter parameters predict the power flux density at the border between PSAs and BTAs, co-channel interference, and adjacent channel interference. These studies can be performed using normal propagation and interference analysis tools, so long as they can handle the moderately large number of interferors involved. The process in each case will entail conducting a path loss and excess path loss calculation from each assumed transmitter at each grid point to each point on a large matrix covering the area of interest. The effects of terrain and earth curvature are included in the calculations, and a propagation model such as free space path loss plus reflection and multiple diffractions is used. The signal powers at each matrix point are accumulated by conversion to pure power in Watts and back to signal power, as described previously.

Once the matrix field is complete, then other results can be derived from it. For instance, the -73 dBW/m^2 contour can be found by interpolating between matrix point powers to route the contour. Contours for D/U signal ratios can be similarly routed by first calculating the power ratios at each matrix point. If not directly available from propagation analysis tools, these studies can be done by exporting the data from such tools and handling some of the data processing in a standard mathematical analysis tool such as a spreadsheet, as was done in conjunction with the field testing conducted in support of the Petition of which this Rationale is a part.

Field Test

In order to confirm that the interference analysis methodology proposed in this Rationale and the associated Petition reasonably predict the level of interference to be expected from a large number of response station transmitters operating simultaneously on the same channel, a field test was conducted as a demonstration of the method. A detailed report of the field test is attached and includes numerous tables and charts that can be of help in understanding the process.[8]

Test design

The field test was conducted in Tucson, AZ, during the period from November, 1996, through January, 1997. A five mile radius, circular cell was designed with 96 grid points as target transmitter locations. The grid points were based on a uniform distribution throughout the cell. Response station transmitters were installed in homes and businesses positioned as close to the target grid points as possible. A total of 93 response stations was installed, the other three having been eliminated because they were located in inaccessible terrain. Each response station was installed with its transmitter operating on a separate carrier frequency so that the signals from each response station could be individually recognized and measured. The carriers from the response stations were unmodulated.

The test design provided for up to 180 measurement sites. The measurement points were in concentric rings spaced ½, 1, 2, and 4 miles outside the theoretical boundary of the cell, i.e., 5.5, 6, 7, and 9 miles from the response station hub. They were spaced every 5 degrees around the periphery of the cell on the ½-mile ring and every 10 degrees around the 1, 2, and 4 mile rings. A total of 136 measurement sites was actually used, the remainder having been cut off from the bulk of the cell by terrain blockage. A truck with a tower and a mobile receiving, measurement, and data collection system was used to make the measurements.

---

[8] See "Field Test Report: Accumulation of Return Path Transmissions in Two-way Wireless Cable Systems," prepared by George W. Harter, III, Hardin and Associates, Inc. (hereinafter the "Field Test Report.")

Two rounds of tests were conducted. These involved two different sets of response station transmitting antennas, one with 12 dBi gain and the other with 24 dBi gain. The antennas were all aimed at the response station hub, a mid-rise building known as Tucson House. The power output from each of the response station transmitters was adjusted, to the extent possible, for a uniform received signal level at Tucson House. Some response stations were unable to achieve the target received signal level at Tucson House because of a combination of terrain or foliage blockage and limited available transmitter power. They were operated with the maximum transmitter power available.

Measurements made

At each of the measurement sites, sets of observations were taken at each of three elevations above ground – 30, 40, and 50 feet. This provides the ability to examine the data to determine whether each site was receiving the various signals with smooth or disturbed fields, which provides some indication of the nature of the path. It also allows examination for the presence of nearby blockages.

Data was collected in three ways. (1) A direct measurement was made of the received power level across the entire spectrum used by all of the response stations. This was done using a special measurement technique in a spectrum analyzer that determines the power in a precisely defined band. (2) Plots were taken of the received signal spectrum in ½ MHz blocks, requiring 8 such plots to cover the 4 MHz occupied by all of the response stations. (3) Data files were captured providing sampled power levels for some 400 points in the spectrum of the same ½ MHz blocks as used for the plots. These data allow after-the-fact determination of the combined power levels of any subsets of transmitters desired and can also confirm the on-site total power measurements. A total of 13,056 data files was collected, including both the graphical spectrum plots and the spreadsheet-like sample data.

Field Test Results

The results of the field test substantially confirm the validity of the method for predicting accumulated signal power from a multiplicity of statistically-located transmitters, as discussed in detail in the Field Test Report. They fully justify the use of a statistical approach to determining the interference potential from a large number of response stations located throughout a response service area. The power levels calculated by these methods can then be used in more conventional interference prediction methodologies either with existing tools or with easily achieved extensions to those tools.

Predicted power levels compared

In analyzing the data from the field test, the proposed prediction methodology was followed as a separate task, and the resulting sets of data were compared. Using the grid of 96 target points from the field test, the points were split into two groups in checkerboard fashion. The predicted power levels from each of the two groups were calculated at each of the ideal measurement points on the ½-mile measurement line. The differences between the calculated signal levels from each of the two groups were then compared at each of the ideal measurement points.

With 96 grid points, the differences calculated between the two groups did not fall within the 3 dB threshold at all measurement points. With the proposed method, this would normally trigger the use of a larger number of grid points. Given the exigencies of fielding nearly 100 response stations in a short period, a determination was made that the smaller number of response stations would be used in the field test than points that normally would be required in an analysis under the methodology. This decision had the effect of making the analysis method even more conservative and reliable, so long as it could be shown that the interference measured in the field was actually less than the interference predicted by the proposed methodology, even with the smaller number of emitters.

Conservative results achieved

In fact, the conservative results sought were achieved. As shown in the analysis in the Field Test Report, the measurement results fell at or below the predicted power levels in all cases but one. In that one case, there was a higher than predicted signal level measured in the field at one receiving antenna height (30 feet) that resulted from a limitation in the resolution of the 3-second terrain database in a hilly area. In many cases, the signal levels found were substantially below those predicted, sometimes at Tucson House, sometimes at the measurement locations, frequently at both, which results were likely caused by the existence of foliage and local blockages that could not be included in the prediction method.

The effects of the use of different antenna patterns are readily apparent in the data collected in the field test. When higher gain, lower sidelobe antennas are used, the relative amount of potentially interfering signal power appearing outside the cell is reduced when the power received at the response station hub is held constant. This confirms the need to include the worst case antenna patterns to be used at any maximum height and maximum power level in the interference studies and the authorization of the response station hub.

The overall result of the field test was to confirm the adequacy of the proposed methodology for interference analysis and the proposed requirements for specifications to be provided in authorization applications.

Conclusion

A cohesive set of technical changes have been proposed to the FCC Rules to support the practical implementation of both two-way operation and distributed transmission. Each technical change proposed has been discussed in this Rationale from the point of view of explaining it, providing background information, and, where necessary, defining procedures. In particular, the methodology proposed for analyzing interference from a large number of response stations has been field tested and shown to provide adequately conservative prediction of accumulated signal power.

The use of two-way operation and distributed transmission in wireless cable systems is ready to move forward. The proposals included in the accompanying Petition for Rulemaking are carefully constructed to make implementation of these new methods of operation practical under the Rules. This document has shown the technical logic underlying the proposed Rules changes.

FIGURE 6.1 - 12 DBI TRANSMIT ANTENNA, MEASURED VS PREDICTED ACCUMULATED POWER, 30' RECEIVE ANTENNA HEIGHT, NO TERRAIN EFFECTS

Field Test Report: Accumulation of Return Path Transmissions in Two-way Wireless Cable Systems

Prepared by George W. Harter, III
Hardin and Associates, Inc.

Supported by S. Merrill Weiss, Consultant in Electronic Media Technology/Management

February 10, 1997

Acknowledgment

The tests conducted and reported in this document could not have been accomplished without the support and contribution of numerous people. The author would like to express a special thanks to Merrill Weiss whose guidance and leadership were the driving force behind this project. And to Mike Denny, Angie Steiers, Keith Neff, Mike Williams, Bob Solari and other members of the People's Choice TV staff in Tucson who hosted and participated in the test. The intense effort put forth by People's Choice TV personnel in the implementation of the test system guaranteed the success of the project.

Also, a special thanks to Conifer Corporation, Andrew Corporation and Comwave for the contribution of equipment to the test.

Table of Contents

0

Introduction

Commercial equipment to transmit digitally compressed signals in wireless cable systems is rapidly approaching the point of wide spread distribution within our industry. However, the regulatory guidelines established by the Federal Communications Commission ("FCC") and currently in place allowing transmission of digitally compressed signals represent an interim set of standards. These guidelines allow digital transmissions and establish very conservative standards for interference protection. These interim standards do not allow the full advantages of digital operation to be exploited by a wireless system operator. Now is the time for the establishment of permanent FCC rules governing the licensing and operation of digital signals in wireless cable systems.

To this end, a task force was formed consisting of several wireless cable system operators, equipment suppliers, consulting engineers and attorneys to review the existing rules and propose changes to accommodate the requirements of wireless cable digital system designs. The first phase of this process is to propose rule changes to modify existing booster and response channel regulations which allow digital two-way and cellularized transmissions. One of the major issues arising from the proposed rule changes is how to calculate the potential for interference from a cell consisting of numerous return path transmitters. A methodology must be created to allow engineers to predict how multiple return path signals will accumulate at points outside of the cell boundary. Once accumulated, the interference potential of these signals can then be determined.

A methodology has been created and is outlined in detail in the rationale document submitted in support of the proposed rule changes. In order to confirm the proposals set forth in the methodology, a field test was designed and implemented in Tucson, AZ. A cell was constructed with actual return path transmitters and measurements were taken in a mobile test van at points outside of the cell to verify the individual and the accumulated power level from each return path transmitter. This data was taken for return path transmitters operating with a relatively broad antenna pattern and repeated for a narrow transmit antenna pattern. The measured results were then compared to the predicted results to prove the accuracy and conservatism of the proposed methodology.

1

Accumulation Method

The prediction method for accumulating signal power from multiple return path transmitters within a two-way wireless cable system involves three steps. First, a grid of points must be defined within the cell which are representative of the distribution of return path transmitters throughout the cell. A sufficient number of grid points must be chosen so as to be statistically representative of the distribution of return path transmitters within the cell. Achievement of the appropriate number of grid points is verified by assigning a single transmitter with the maximum EIRP, height and worst case combined antenna characteristic for the region to each grid point. A propagation analysis is then performed to calculate the aggregated power of one half of the total grid points in the cell on a measurement line ½ mile outside of the cell and comparing the result to the same calculation using the other half of the grid points. The two measurements should be within 3 dB of each other at each measurement point along the measurement line. The propagation model should be run over flat earth and should not include the effects of terrain. If the two measurements are not within 3 dB of each other, the number of grid points must be increased and the procedure repeated.

After the correct number of grid points is defined and verified, the second step involves the determination of the maximum number of transmitters which could be transmitting and causing interference on a given channel or subchannel at one time. This is determined by the technical design of the return path system and any statistical assumptions required to complete the analysis. Once the number of transmitters is determined, they are then divided up and assigned to each grid point based on a uniform distribution of transmitters within each response service region in the cell.

The third and final step of the analysis involves a calculation of the aggregated power from each grid point to points outside of the cell boundary where interference protection is necessary per FCC rules. The maximum EIRP, maximum antenna height and worst case composite transmit antenna pattern for each region of the response service area is utilized.

2

System Design

There are many variables to be decided upon in the RF portion of a cellular design. Some of these include size of the cell, shape of the cell, power levels of the return path transmitters, antenna patterns, modulation techniques and many more. However, there are certain parameters of the system design which are critical to the analysis of the potential for a cell to generate interference. The critical parameters are outlined below.

Cell Shape

The shape of a cell will be dictated by the physical location of the population within a market and the location of the cell hub. Cell shapes could be circular, cardioid, elliptical, tear drop or many other shapes depending upon the market area. It is believed the most common shape will be circular with the hub lying at the center of the circle. This shape will also produce the maximum possible radiation over the widest arc (360 degrees) of all the possible shapes.

The accumulation method requires cell grid points be distributed uniformly throughout the cell, independent of the cell shape. The grid points must be placed at locations within the cell to achieve a uniform distribution of power at the measurement line surrounding the cell boundary. Therefore, the accumulation method will account for whatever cell shape is designed.

Cell Size

Again, the size of a cell will vary significantly based on the modulation technique, power capability of the return path transmitters and path obstructions caused by foliage, terrain and other physical structures in a given market. The maximum possible cell size for incumbent wireless operators would be a cell coterminous with the FCC protected service area boundary and having a radius of 35 miles. A larger cell could be constructed by a BTA winner if the BTA were large enough to support the cell. Large cell sizes may be practical for commercial applications where the return path transmit antenna or the hub receive antenna will have sufficient height to achieve unobstructed electrical paths between sites. However, cell sizes ranging from 3 to 10 miles in radius will be more practical for the average consumer installation with antenna heights limited to roof top levels or slightly above.

The prediction methodology requires the grid points be distributed evenly throughout the cell, independent of the cell size, such that a uniform power distribution is achieved outside of the cell at the measurement line. Therefore, cell size is accounted for in the proposal.

Antenna Pattern

Return path systems will use typical wireless cable receive antennas as transmit antennas. Gains will typically range from 12 to 27 dBi and the patterns from very broad to extremely narrow. The pattern of the antenna is extremely important in predicting the level of signal to be accumulated outside of the cell boundary. Obviously, the broader antenna patterns will radiate signal in more directions than narrower patterns and have the potential to create interference over a larger area. Cells may utilize more than one antenna pattern to achieve the necessary performance levels. Therefore, worst case composite antenna patterns must be utilized when calculating the potential for interference from a cell. A composite pattern is created by overlaying the patterns of all antennas to be used in a system and taking the maximum power generated in each direction by any one of the antennas.

The composite antenna pattern must be utilized in the analyses performed in support of the predicted signal accumulation.

Power Level

Most return path systems will be designed to achieve a consistent received signal level at the hub from every return path transmitter in the cell. The quality of the propagation path from the return path transmitter to the hub will significantly affect the ability to achieve this goal. An operator will attempt to achieve an unobstructed electrical path to the cell hub by varying the return path transmit antenna height as much as possible. Also, an operator will control the radiated power level of the return path system by varying antenna size, placing attenuation in the output of the transmitter or placing amplification in order to achieve the desired received signal level at the hub. However, a significant number of transmit sites could be running at maximum power in order to attempt to overcome signal loss due to obstructions.

Therefore, the accumulation methodology will assume all return path transmitters are operating at the highest possible power in the system design. This conservative approach will produce the worst case interference levels possible in a system design.

Multiple Cells

Some system designs will consist of multiple cells within a geographic area. Each of the individual cells can be analyzed by the accumulation methodology described previously.

If multiple cells exist, the interference potential from each individual cell can be calculated at the boundary of interest and summed to predict the interference potential of the entire system.

3

Test System Design and Implementation

Cell Design

A test cell was designed to verify the prediction methodology and to be consistent with the system design characteristics described previously. A circular cell with a radius of 5 miles was selected. In order to evaluate the effects of return path transmit antenna variations on the prediction methodology, the test was run once using a broad beamwidth, low gain antenna. Upon completion of the first round of testing, the return path antennas werer changed to a narrow beamwidth, high gain antenna and the tests were repeated. The antenna patterns are attached as Figure 4.1.

A grid of theoretical return path sites within the 5 mile cell was defined using 96 evenly spaced points with slightly less than 1 mile spacing as shown in Figure 4.2. The grid points were assigned numerical identification numbers. An analysis was performed as described previously in the accumulation methodology to verify the correct number of grid points. The 96 points were divided into halves and a separate power calculation for the odd and even halves was conducted at 72 test points on a measurement line ½ mile outside of the cell boundary. A free space propagation model was utilized with no terrain or earth curvature included in the analysis. The results of the analysis are attached as Table 4.1 and Figure 4.3. As the results show, the power levels at all of the test points on the measurement line for the odd numbered sites is not within 3 dB of the measurements at the same point for the even numbered sites. Therefore, a sufficient number of grid points has not been chosen for the analysis. However, from a practical standpoint, the implementation of a test system with more than 96 return path transmitters was not practical and is not necessary in this instance since the goal of this field test is prove the prediction model accurately predicts the levels of actual return path transmissions outside of a cell boundary. If this were an actual design for licensing purposes, we would need to increase the number of grid points and repeat the analysis.

The power levels were dictated by the return path transmitters available for the test. The typical power output capability for a transmitter is +7 dBm with a 1 dB compression point of approximately +10 dBm. Each transmitter output was attenuated as necessary to achieve the desired receive signal level at the cell center. If insufficient power was available to achieve the desired receive signal level at the cell center, the transmitter was allowed to operate at maximum power output.

The test primarily involved measurement of the total accumulated power from each of the transmitters to points outside of the cell. However, recording the power contribution from individual transmitters allows analyses of various distributions of transmitters within the cell. This can provide useful information on how various grid sizes or population densities can affect the studies. Therefore, a frequency plan was developed whereby each transmit site operated on an individual frequency within the MDS2-A channel bandwidth. Each of the sites transmitted an unmodulated carrier. A spectrum analyzer plot of the entire MDS2-A channel at each of the test points allowed the identification of the power level contributed from each individual return path transmitter based on frequency. The frequency plan is attached as Table 4.2 and the frequency zones are shown on the map in Figure 4.4.

Implementation

The cell design was implemented in Tucson, AZ within an existing People's Choice TV wireless cable system. A developmental application for the use of MDS2-A was filed and received to allow operation of the multiple return path transmitters for a limited period of time. The selection of Tucson as the test site offered several advantages:

(1) There is an appropriate area where the terrain is reasonably flat and accommodating to the insertion of a 5 mile cell within the urban areas of Tucson. The southwest quadrant of the cell did contain a small mountain. However, this provided the opportunity to install a return path transmitter on top of the mountain to simulate a very high installation. Also, several transmitters were installed behind the mountain to prove the effects of terrain blockage on accumulated signal reduction.

(2) An ideal hub site at the center of the cell was available to construct a receive site for alignment of the installations at each of the transmit sites. An apartment building know as Tucson House was utilized which is approximately 215' above ground level.

(3) The climate is mild and very little impact on signal propagation characteristics was expected.

(4) The existing wireless cable subscribers in Tucson offer an excellent pool of potential installations.

The one disadvantage in utilizing Tucson came from the fact that existing subscriber installations have very low receive antenna heights. The Tucson wireless transmit site is